AIRCRAFT / PAVEMENT CLASSIFICATION RATING
ACR / PCR

Central American and Caribbean Working Group (NACC/WG)
Aerodromes and Ground Aids (AGA) Implementation Task Force
Meeting (NACC/WG/AGA/TF/2)

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A NEW ERA IN AIRPORT
PAVEMENT ASSET MANAGEMENT

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ACR-PCR

What Airport Pavement is?

A major airport asset which allows aircraft to taxi, take-off, land and park
30% of airport construction cost and **up to 50% of annual airport infrastructure maintenance cost**

Must be capable of:

- ✓ Satisfying bearing strength capabilities to accommodate an analyzed aircraft mix (Vertical)
- ✓ Providing sufficient friction characteristics to maintain aircraft under control in critical phases (horizontal)

What we don't want

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- **A Pavement Rating System** Classifies the pavements with regard to their **structural** capacity of sustaining a forecasted aircraft mix
- Based on two elements associated to the **PAVEMENT** (1) and the **AIRCRAFT** (2)

AIRCRAFT

Aircraft / Pavement Compatibility: A complex equation of paramount importance

Still comparing two numbers, but changing radically the way of determining them!

ACR

PAVEMENT

For SUSTAINABLE and SAFE OPERATIONS at optimized COST

PCR

If ACR ≤ PCR, the aircraft can operate on the pavement without restriction

If ACR > PCR, some restrictions (on operating weight and/or frequencies) may apply

New Provision on **OVERLOAD** operations

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Key changes

- What **DOES NOT** change is the comparison of ACR and PCR as the core principle of the method:

If ACR $\leq$ PCR, the aircraft can operate on the pavement without restriction

If ACN > PCN, some restrictions (on operating weight and/or frequencies) may apply

- What **DO** change are the procedures for determining the ACR and PCR:

  - Now based on rational models allowing the calculation of pavement responses (stresses, strains, deflections) from Layered Elastic Analysis (LEA)
  - Pavement **damage** is then quantified based on these responses and a specific **damage model**

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Key changes

In **practical terms**, the ACR-PCR method will lead to:

- New ACR values (calculated and published by aircraft manufacturers)
  – Still computed based on the combined result of aircraft wheel loads, tire pressures and landing gear geometry

- New PCR values (calculated and published by airports)
  – Reporting format (one letter and a series of four letters) is unchanged
  – A model procedure for PCR determination is provided by ICAO (filling the lack of ICAO guidance for PCN evaluation), it can be parameterized to handle national or local specificities (e.g. subgrade failure model)
  – The PCR is computed based on the accumulated pavement damage produced by entire traffic mix (CDF)
  – Subgrade are now characterized by the **elastic modulus E for both flexible and rigid pavements** (unified characterization)

- Unchanged general approach (comparison of ACR and PCR)

Both ACR and PCR numerical values are approximately one order of magnitude (10x) higher than the ACN and PCN number. However, there is no ability to convert between ACN and ACR, nor between PCN and PCR.

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New overload operations procedures

- A new approach for overload operations (i.e. when ACR > PCR)
  - "ICAO allowance" is increased to 10% of the PCR for both flexible and rigid pavements
  - Overloads in excess of 10% may be allowed if justified through a technical analysis of the impact on pavement damage, consistent with the PCR philosophy

Both ACR and PCR numerical values are approximately one order of magnitude (10x) higher than the ACN and PCN number. However, there is no ability to convert between ACN and ACR, nor between PCN and PCR.

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Why such a change?

ACN – PCN

- Unable to consider accurately "complex" landing gear configurations
- Unable to account for the improved characteristics **of new-generation pavement materials**
- inconsistent with **modern pavement design methods**
- Unable to consider the variability of landing gear transverse positions (different overall wheel tracks)
- **Lack of guidance for PCN determination**

ACR – PCR

(Applicable Nov. 28th, 2024)

A new game changer for all involved stakeholders

An urgent need to substitute the former conservative empirical methods with a more accurate and predictive model for an **optimized usage of airport pavements**

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THE ACR

- The Aircraft Classsification Rating (ACR) is a number expressing the relative effect on an aircraft on a pavement for a specified standard subgrade strength
- 4 standard subgrade strength categories are define, common to flexible and rigid pavements

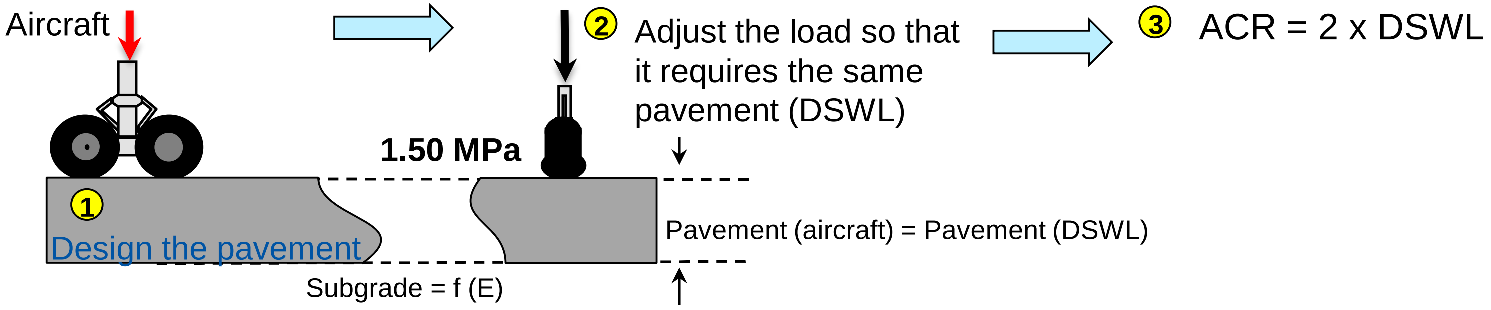
CAT A	CAT B	CAT C	CAT D
E = 200 MPa	E = 120 MPa	E = 80 MPa	E = 50 MPa

- The ACR is numerically defined as twice the Derived Single Wheel Load (DSWL), expressed in hundreds of kilograms
- The DSWL is defined as the single wheel load (with contact pressure of 1.50 MPa), that is equivalent (according to a defined criterion) to the aircraft on a given pavement structure

ACR-PCR

ACR concept

- Similarly to the ACN, the ACR is computed as twice the **Derived Single Wheel Load (DSWL)**, which is the load on a single, isolated wheel (with fixed tire pressure) requiring the same pavement thickness as the considered aircraft



- The changes vs. ACN are:

1. The pavement is designed according to a **rational pavement design procedure** (vs. CBR or Westergaard procedures): **this is the major change vs. ACN and the key part of ACR computation**
2. The DSWL is computed for a tire pressure of 1.50 MPa (vs. 1.25 MPa)
3. The ACR is expressed in hundreds of kilograms (vs. tons)

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THE PCR

- The Pavement Classsification Rating (PCR) is a number expressing, on the same scale than ACR, the **load-carrying capacity of a pavement for unrestricted operations**
- The PCR of a pavement should reflect the pavement design with respect to the traffic it is intended to serve
- The PCR procedure should ensure that:
  - If the pavement **CDF is equal to or lower than 1.0** (well or over-designed), **no aircraft weight restriction should occur**
  - If the pavement **CDF is higher than 1.0**, **weight restrictions should apply** to one aircraft at least
- A generic PCR computation procedure with several degrees of freedom (e.g. pavement damage model) is proposed

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THE REPORTING FORMAT

- Similarly to the PCN, the PCR represents the pavement bearing strength (on the ACR scale) for <u>unrestricted operations</u>
- A PCR should be determined by the airport operator for all the pavements intended for aircraft of mass greater than 5.7 tons
- The PCR should be published in the Aeronautical Information Publication (AIP) according to the format defined in ICAO Annex 14 (§ 2.6.6)

PCR 560 / F / B / W / T

PCR number

Pavement type
F: Flexible
R: Rigid

Subgrade strength category
A: High
B: Medium
C: Low
D: Ultra low

Maximum allowable tire pressure
W: No pressure limit
X: 1.75 MPa
Y: 1.25 MPa
Z: 0.5 MPa

Evaluation method
U: Using aircraft experience
T: Technical evaluation

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Cumulative damage factor - Definition

- The cumulative damage factor (CDF) is the amount of the structural fatigue life of a pavement which has been used up. It is expressed as the ratio of applied load repetitions to allowable load repetitions to failure, or, for one airplane and constant annual departures:

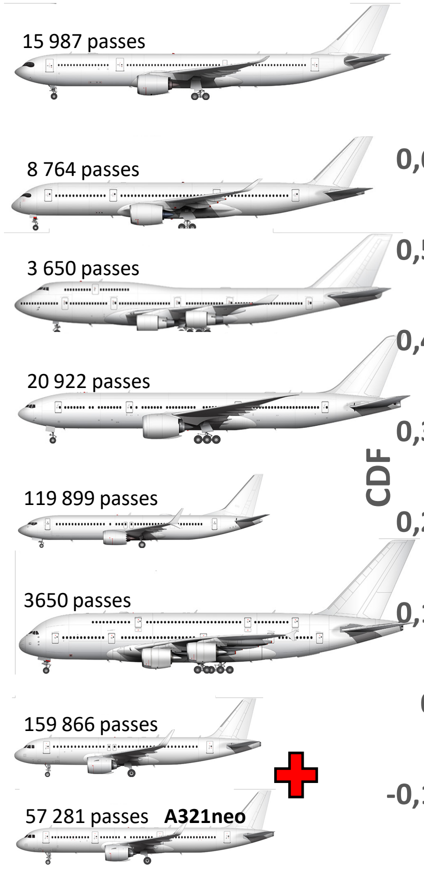
$$CDF = \frac{Applied\ coverages}{Coverages\ to\ failure}$$

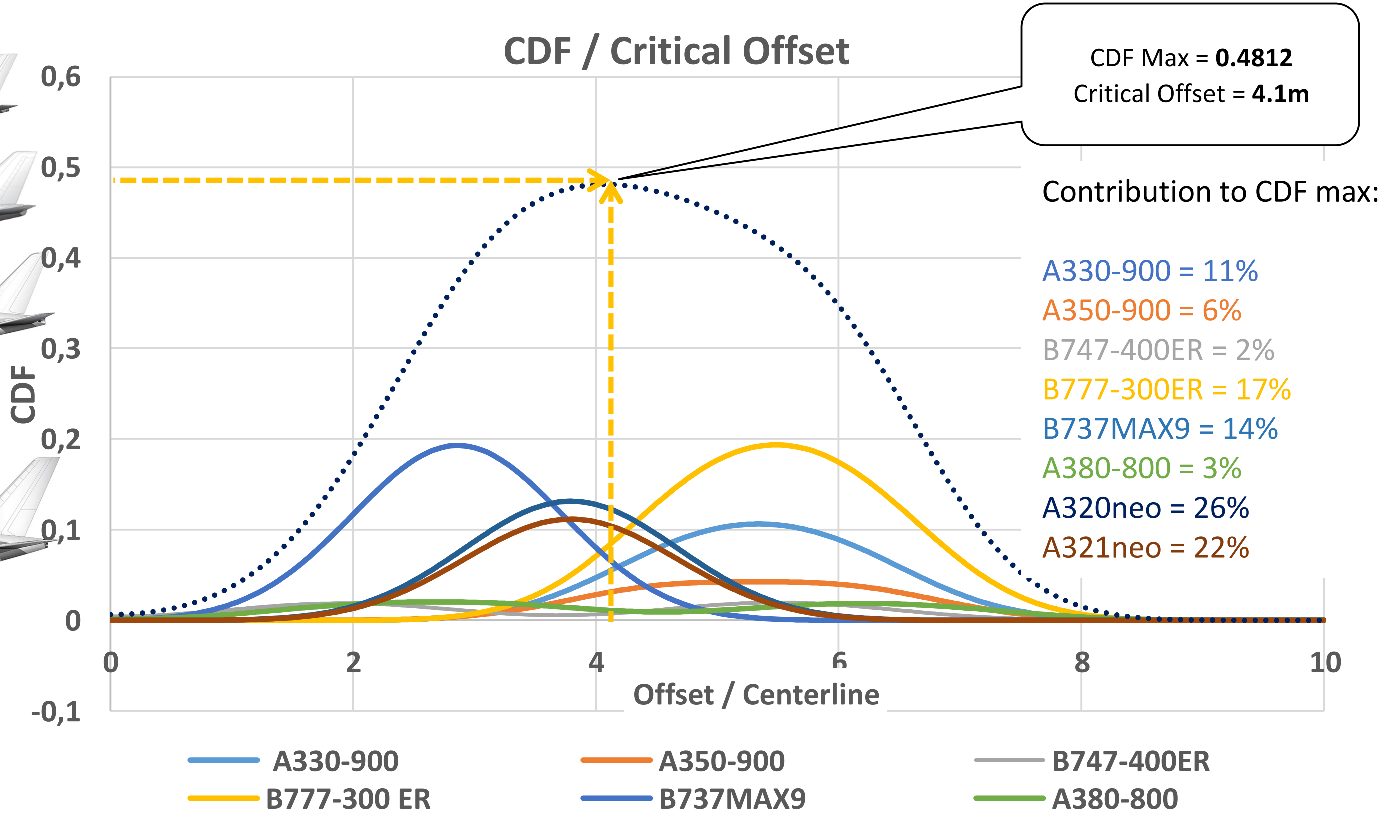
  where a coverage is one application of the maximum strain or stress due to load on a given point in the pavement structure.

  - When CDF = 1, the pavement subgrade will have used all of its fatigue life;
  - When CDF < 1, the pavement subgrade will have some remaining life and the value of CDF will give the fraction of the life used;
  - When CDF > 1, all of the fatigue life will have been used and the pavement subgrade will have failed.

- For multiple aircraft (Miner's Rule):
  $CDF = CDF_1 + CDF_2 + \cdots + CDF_N$ (Where CDF_i is the CDF for each airplane in the traffic mix and N is the number of airplanes in the mix.

THE CUMULATIVE DAMAGE FACTOR (CDF)





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Cumulative damage factor

- The CDF is the core principle of the ACR-PCR.
- It depends of many factors such as:
  - The design criterion,
  - The elementary damage
  - The damage model,
  - The lateral wandering calculation method
  - The standard deviation
  - Etc…
- When using a software, need to understand the black box!

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GENERIC PCR COMPUTATION PROCEDURE

Traffic data

Pavement data

1. Identify the aircraft with the maximum ACR (at its operating weight) in the traffic AC_{max}

$i = 1$

2. Compute the maximum cumulated pavement damage $CDF_{max}{}^{(i)}$ for the current traffic

Using subgrade failure model consistent with design parameters

3. Select the aircraft $AC^{(i)}$ that contributes the most to $CDF_{max}{}^{(i)}$

4. Keeping only $AC^{(i)}$ in the traffic, adjust its number of passes $N^{(i)}$ such that it produces the same pavement damage than the entire traffic $CDF_{max}{}^{(1)}$

Make aircraft equivalent to the entire traffic

5. Keeping only $AC^{(i)}$ in the traffic with the adjusted number of passes $N^{(i)}$, adjust its weight $W^{(i)}$ such that it produces a pavement damage = 1.0

Make equivalent aircraft compatible with the pavement

6. $PCR^{(i)}$ = ACR of $AC^{(i)}$ with operating weight $W^{(i)}$

7. $AC^{(i)}$ is AC_{max} ?

No: Remove $AC^{(i)}$ from the current traffic

$i = i + 1$

Yes: $PCR = \max_i PCR^{(i)}$

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PCR DETERMINATION AND PUBLICATION – EXAMPLE 1.1

- A (new) flexible runway (**F**) is designed according to the French rational design method.
- The subgrade modulus is estimated as: $E = 80\ MPa$ ⇨ subgrade **category C**
- The surface layer is made of asphalt concrete able to withstand the highest tire pressures ⇨ tire pressure **category W**
- The damage model for the PCR evaluation is the same than used for pavement design (French DGAC-STAC damage model)

EB-BBA2 **Wearing course**	$E = 5500\ MPa$	$\nu = 0.35$	$t = 6\ cm$
EB-GB3 **Base course**	$E = 14000\ MPa$	$\nu = 0.35$	$t = 13\ cm$
GNT1 **Sub-base**	$E = 450\ MPa$	$\nu = 0.35$	$t = 25\ cm$
Subgrade	$E = 80\ MPa$	$\nu = 0.35$	$t = \infty$

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PCR DETERMINATION AND PUBLICATION – EXAMPLE 1.2

- Traffic forecasted over the 10-year pavement life

Aircraft	Operating weight (t)	Passes
A319neo	75.9	258 542
A320neo	79.4	232 094
A321neo	97.4	210 424
A330-200	233.9	51 405
A330-300	233.9	19 396
A350-900	268.9	8 971
A380-800	571.0	29 123

Aircraft	Operating weight (t)	Passes
737-800	79.2	98 433
757-200	116.1	4 352
767-300	163.8	17 094
767-400ER	204.6	3 415
787-8	228.4	10 885
787-9	254.7	16 045
777-200	248.1	40 378
777-300ER	352.4	37 842

- Aircraft wander is considered as per the French rational design method for flexible runways (Gaussian distribution, σ = 75 cm = 29.53 in)

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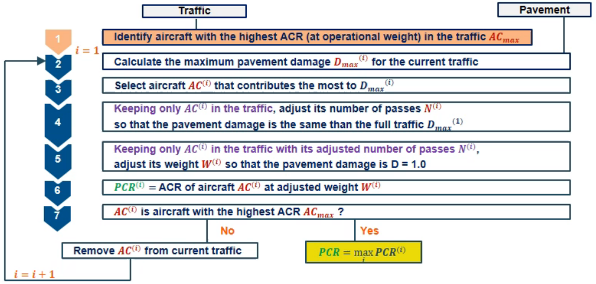
PCR DETERMINATION AND PUBLICATION – EXAMPLE 1.3



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PCR DETERMINATION AND PUBLICATION – EXAMPLE 1.4

- The PCR should be reported as **800 F/C/W/T**

- The PCR would have been reported as 590 /F/C/W/T based on the A321neo if only the most contributing aircraft is considered
- This would have lead to weight restrictions for most of the long-range aircraft, despite the pavement being properly designed for the entire traffic

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PCR DETERMINATION AND PUBLICATION – EXAMPLE 2.1

Pavement structure (Design life = 10 years)

Surface course EB-BBSG3	$E = f(\theta, freq)$	$\nu = 0.35$	$t = 6\ cm$
Base course EB-GB3	$E = f(\theta, freq)$	$\nu = 0.35$	$t = 18\ cm$
Subbase 1 GNT1	$E = 600\ MPa$	$\nu = 0.35$	$t = 12\ cm$
Subbase 1 GNT1	$E = 240\ MPa$	$\nu = 0.35$	$t = 25\ cm$
Subgrade	$E = 80\ MPa$ (CAT C)	$\nu = 0.35$	$t = \infty$

Traffic (simplified)

#	Aircraft model	Operating weight (t)	Annual departures	ACR @ operating weight
1	A321-200	93.9	14600	550
2	A350-900	268.9	5475	720
3	A380-800	571.0	1825	650
4	B737-900	79.2	10950	450
5	B787-8	228.4	3650	680
6	B777-300ER	352.4	4380	780

1 The 777-300ER is the aircraft with the maximum ACR (AC_{max})

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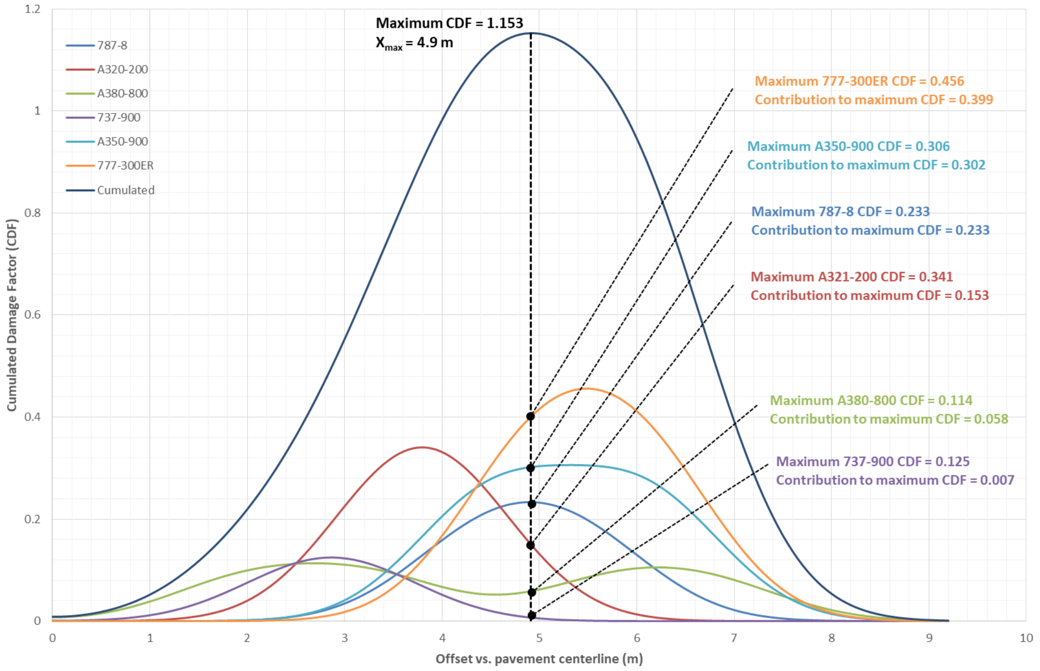
PCR DETERMINATION AND PUBLICATION – EXAMPLE 2.2



2. The maximum CDF is $CDF_{max}{}^{(1)} = 1.153$

3. The 777-300ER is the aircraft contributing the most to $CDF_{max}{}^{(1)}$

4. When considered alone, the 4380 annual departures of the 777-300ER produces a CDF of 0.456.
   The annual departures to produce $CDF_{max}{}^{(1)}$ are: $N^{(1)} = 4380\frac{1.153}{0.456} = 11073$

5. In order to reach a maximum CDF = 1.00, the 777-300ER weight must be reduced from 352.4 t to $W^{(1)} = 341.1\ t$

6. $PCR^{(1)}$ = ACR of 777-300ER at $W^{(1)} = 740\ FC$

7. Since the 777-300ER is AC_{max}, no additional iteration is required

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PCR DETERMINATION AND PUBLICATION – EXAMPLE 2.3

- Using design parameters different of those used for pavement design lead to inconsistent PCR determination.
- From the previous aircraft mix and pavement characteristics, see below examples using different design parameters

Subgrade Failure model	Wheels in tandem (multi-axle wheels)	CDF Max./ Res. Life (Str)	PCR	Comment
WÖLHER	**Integral form**	**1,15 / 8,7 yrs**	**740 FCXT**	**Match design parameters**
WÖLHER	TGF (longitudinal P-to-C ratio)	1,81 / 5,5 yrs	622 FCXT	Inconsistency
BLEASDALE	Integral form	0,2 / 50 yrs	900 FCXT	Inconsistency
BLEASDALE	TGF (longitudinal P-to-C retio)	0,55 / 18 yrs	823 FCXT	Inconsistency

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CONSEQUENCES OF PCR INACCURACIES

Under-estimated PCR (overestimated CDF)

➔ Aircraft weight / annual departure restrictions or operations not granted

➔ Pavement usage not optimized, **loss of airport revenues**

Over-estimated PCR (underestimated CDF)

➔ More traffic acceptance (weight/volume) than the pavement is able to withstand over its design life

➔ Premature pavement damage, increase of maintenance / repairs **COSTS**

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OVERLOAD OPERATIONS

- For flexible and rigid pavements, occasional movements by aircraft with ACR not exceeding 10% of the reported PCR should not adversely affect the pavement
- The annual number of overload movements should not exceed approximately 5% of the total annual movements excluding light aircraft

- Overload operations in excess of 10% may be considered on a case by case basis when supported by a detailed technical analysis
- The technical analysis should assess how the overload operations actually contribute to the pavement damage when integrated to the existing traffic, which could be done using the same framework than for the PCR computation

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OVERLOAD OPERATIONS - EXAMPLE

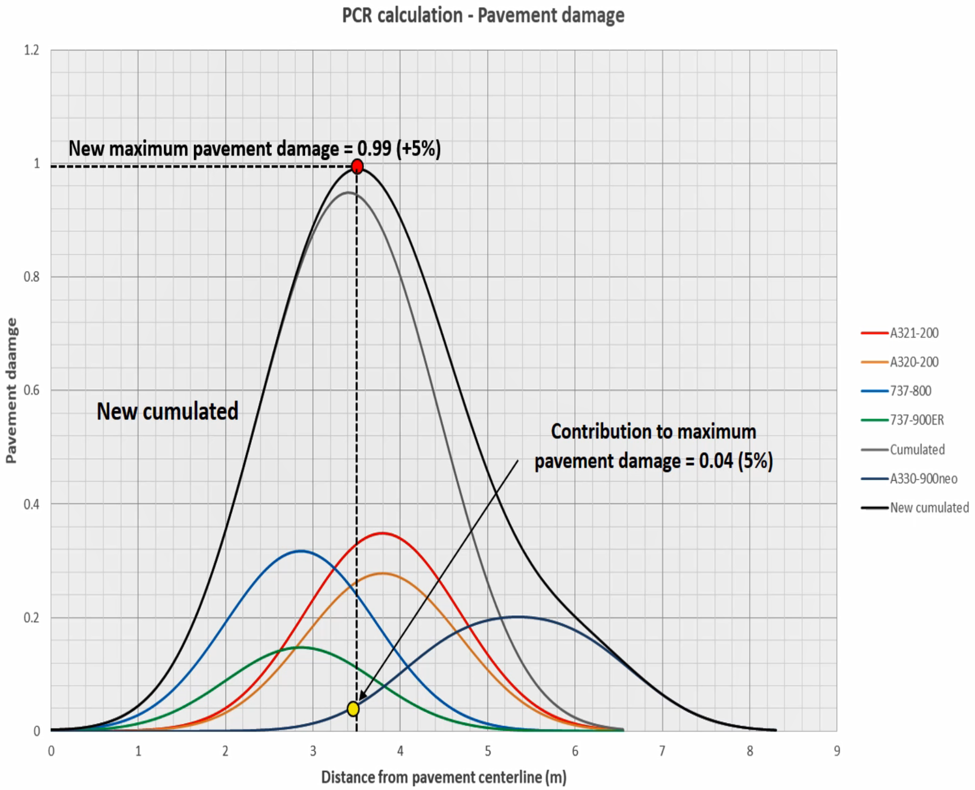
- The PCR also provides a damage-based approach for assessing overload operations

- Example: PCR for the previous all-SA traffic (~25 mvts/days) computed as **560 F/C**

- Airport wants to assess whether it can accept 1 daily operation of A330-900neo (ACR = **710 F/C**)

- ACR/PCR overload is significant (> 25%)
- But actual impact on pavement damage is limited to 5%

⇨ Airport may allow the overload operations



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BENEFITS OF THE ACR-PCR METHOD

- Overcomes the identified limitations of the current ACN-PCN system and allows a full consideration of the latest evolutions in the field

- Provides several benefits to airport owners
  - Optimized usage of their pavements
  - Improved pavement life predictability
  - Availability of a generic PCR computation procedure
  - Unified soil characterization for both flexible and rigid pavements

- Benefits to airlines and the whole air transport community by allowing optimized operating weights and frequencies without over-conservatism

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What are the requirement and steps for the transition?

1. DATA COLLECTION
   i. Pavement description (if not known, evaluation through non destructive tests, lab tests)
   ii. Trafic mix (actual and forecast over the evaluation period)

2. PCR determination for each & every airport maneuvering area (Apron, parking, taxiway, runway)

3. PCR Publication (AIP update)

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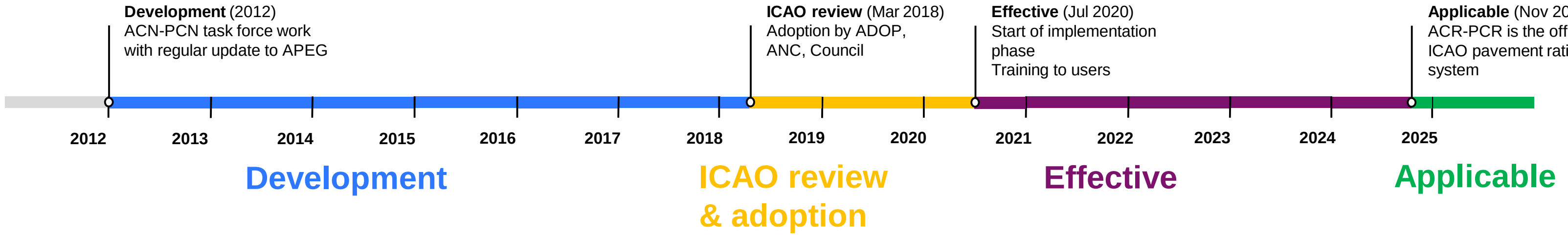
ACR-PCR method timeframe

- The ACR-PCR method was finalized by the APEG beginning of 2018, followed by the full ICAO review and adoption process
- The ACR-PCR method has been **effective** since July 2020
- The method will be fully **applicable** in November 2024



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ICAO Support

[Airport Pavement Strength Rating]()

[Overview of Airport Pavement Strength Rating]()

GLOBAL AVIATION TRAINING

Annex 14 Volume 1, Aerodrome
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ADM Part 3 – Pavements
Doc 9157
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REFERENCE DOCUMENTS

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